BWA/cgr

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26 May 1994

MINUTES OF PS TECHNICAL MEETING N° 58
held on 25th May 1994

Laser Ion Source

Present : *B.W. Allardyce, J. Bosser, M. Bouthéon, R. Cappi, M. Chanel, V. Chohan, J. Collier, J.P Delahaye, R. Garoby, J. Gruber, H. Haseroth, K. Hübner (AC), A. Kuttenberger, K. Langbein, P. Lefèvre, A. Lombardi, K. Masek, W. Pirkl, K. Schindl, C. Serre, T. Sherwood, G. Tranquille*

Absent : *J. Boillot, J. Boucheron, H. Koziol, S. Maury, F. Perriollat, J.P. Ruinaud*

1. Previous technical meetings have been held on this subject (N°12 on 12 September 1991 and N°19 on 30 January 1992). R. Sherwood presented the important modifications that have been made to the apparatus in the last 2 years which have allowed such exciting new results to be obtained. These are essentially the new target and expansion chambers, the laser geometry and the addition of the LBL RFQ.

2. J. Collier presented the details of the apparatus and showed the latest results; over 100 mA of Al ions of mixed charged states for about 5 µsec are extracted from the source. Unfortunately the LBL RFQ was designed for 14 kV extraction voltage (Al^{10+}) so there is heavy space - charge blowup. However about 3 mA of this passes through the RFQ to be analysed at the end of the line as Al^{9+} and Al^{10+}. This is roughly 15 times more intense than the $^{32}S^{12+}$ ions which were used a few years ago with the same RFQ on linac 1. J. Collier indicated he was confident that a laser ion source could be built to give Pb^{25+} of sufficient intensity (6 mA for 5 µsec) to be able to fill LHC in a few minutes, using single turn injection into the Booster, and that sufficiently intense lighter ion beams would also be possible, based on the experience with Al.

3. The implication of this success is that the laser ion source could possibly become a serious candidate for providing the ion beams needed in the future by LHC (as an alternative to, or as a complement to, the presently-envisaged scheme whereby the ions are stored and cooled in LEAR before going to LHC). It was generally agreed that these new results need further study before we can confidently say how they will impact on the proposed scheme of ion acceleration for LHC.

4. J. Collier then presented the immediate next steps foreseen by the group which are the completion of X-ray imaging work, measurements with higher extraction voltages and emittance measurements. He then explaned the longer term future possibilities.

5. H. Haseroth summarised by noting that a decision is needed on future development work. It is clear that if the laser ion source is to become a serious candidate for LHC ions a new RFQ is required (the present one limits the measurements to 9^+ and 10^+ Al), a move to a zone with more space is needed (the apparatus has outgrown the present location), and a more powerful laser is needed (this is not a technological problem). J. Collier suggests moving to bldg 236. Note that copies of the transparencies of Sherwood, Collier and Haseroth were made available at the meeting and further copies are available from J. Collier.

6. During the discussion of these interesting results K. Schindl presented a table (see annex) of possible Pb intensities leading to the required LHC luminosity, and W. Pirkl presented ideas on a new RFQ (see annex) with an exchangeable internal electrode structure. Such an RFQ might only cost around 100 kCHF (plus pumps and supports), but a 100 MHz transmitter would be much more (0,5 to 1,0 MCHF). R. Sherwood suggested that although the situation with the laser ion source was potentially very exciting, the group should first demonstrate that it can produce, accelerate and handle the required Pb intensities before making any promises to LHC.

B.W. Allardyce

LHC BASIC (= NO ACCUMULATION) Pb ION FILLING SCHEME: INTENSITIES, EFFICIENCIES

(Normalized r.m.s. emittance at collision 1.0 μm)

***Scenario 3:** Straightforward Pb acceleration based on a Laser ion source, realistic efficiencies*

Assumption: Laser ion source yields same number of Pb ions as ECR source

Bunch spacing LHC: 134.7 ns. Bunch harmonics: PSB 4, PS 16, SPS non-integer, LHC 660

Accelerator (or element)	Output β	Output T	Efficiency η	Pb ions per cycle	= LHC bunches	Pb ions per LHC bunch	Comments
Laser ion source	0.0023	2.5 keV/n		8.00 10^9	4	2.00 10^9	6.4 mAe*5 μs Pb^{25+} (same # of ions as ECR source: 80 μA * 400 μs)
RFQ	0.023	250 keV/n	0.9				
IH Linac	0.094	4.2 MeV/n	0.9				
Stripper foil			0.16	1.04 10^9	4	2.60 10^8	Pb^{25+} => Pb^{53+}
PSB injection			1.0				Single turn into ε_n=0.5 μm[1]
acceleration	0.42	94 MeV/n	0.6	6.24 10^8	4	1.56 10^8	RF capture, vacuum[2], ***one ring only***
PS injection			0.95				including PSB-PS transfer
acceleration	0.973	3.90 GeV/c/n	0.7	4.15 10^8	4	1.04 10^8	vacuum[2]. PS cycle time 1.2 sec
Stripping			1.0				Pb^{53+}=> Pb^{82+}. 32 PS batches => SPS
SPS injection			0.95				including PS-SPS transfer
acceleration	~1	177 GeV/n	0.7	8.81 10^9	128	6.88 10^7	4 batches SPS => 1 LHC ring.
LHC injection			0.95				Loss includes transfer. Fill. time ~ 3 min/ring
acceleration	~1	2.78 TeV/n	0.95	3.08 10^{10}	496	6.20 10^7	out of 660 bunch places

[1]Single turn injection into PSB, $\varepsilon_n(1\sigma)$ = 0.5 μm ($\varepsilon(2.4\sigma)$ = 32 μm). Emittance "budget" PSB-LHC: $\Delta\varepsilon_n$= 0.5 μm

[2]Losses due to interaction of electrons with rest gas, changing the charge state of the ion

Overall ion acceleration efficiency between ion source and LHC collision: η = 0.0310

LHC Luminosity: L = 1.11*10^{27} cm^{-2} s^{-1} **(wanted 8.9*10^{26} cm^{-2} s^{-1})**

K.Schindl/PS 10.3.92, revised 19.5.94

Comments concerning the BUILD-or-BUY decision for the Laser-Ion Source RFQ

1.-An RFQ installation for the post-acceleration of the beam generated by the Laser-Ion Source consists of the following parts:

- -RFQ proper equipped with electrodes,
- -RFQ accessories (tuners, loops, vacuum pumps etc),
- -probably a prebuncher to reduce the RFQ length,
- -RF power sources at 100 MHz.

2.-The opportunity exists to procure the RFQ proper outside CERN. The precise scope of the delivery is not yet known; it seems however clear that this RFQ is a provisional "proof-of-principle" device which will not reach the full wanted end energy of 250 keV/u. Quoted price is 50 kCHF; it is admitted that this is a nominal figure far below real expenditure (an approach called "dumping" in economics).

3.-Manufacture at CERN of a comparable RFQ includes the two following steps:

-Construction of a universal RFQ test tank with removable vane supporting structure.
This device is equipped with mounting brackets to allow the mounting of different electrodes (vanes) by screws. No welding is needed, electrodes can be changed easily. Tank length is tailored to the "Legnaro" RFQ whose second set of electrodes can be mounted for tests or as backup RFQ.

This universal test tank should be provided in any case as a working tool and general test stand, from a general budget rather.than a specific project. Construction cost is estimated at 80 kCHF excluding expenditure for engineering/drawing .

-Manufacture of dedicated electrodes for the Laser Ion Source beam.
Due to the use of a prebuncher a relatively short RFQ section can be implemented that requires also comparatively little RF power. Within the limits of the test tank dimension the desired end energy of 250keV/u can thus be approached or even reached if a lower transmission is accepted. More studies are needed to give precise figures. Total cost of a set of electrodes is estimated 28 kCHF.

4.- The RF power amplifier at 100 MHz needs investments that are a multiple of the RFQ cost. In the context of the ISOLDE considerations concerning postacceleration of radioactive beams a figure of 700 kCHF was quoted for an industrial prototype RF chain (excluding low-level preamplifiers and servos).
It would be possible to develop such a chain for ISOLDE at the PS, in collaboration between the HI and RF groups, with guaranteed performance at considerably lower expenditure. The "profit" could be used to cover the chain for the RFQ .

5.-Another source of support, in kind or in money, could come from collaborating institutions for which RFQ subprojects (such as design and manufacture of vanes) are carried out at CERN.

6.- It is true that most of RFQ equipment can be procured outside CERN, but it is also true that other laboratories were less than satisfied with this approach. If it is planned to continue serious RFQ activity here at CERN, some investment like the universal test tank is needed in any case. The next step, construction of the complete RFQ chain for the Laser Ion source is an ideal cristallisation point to maintain and develop all skills that are necessary to make more than minimum contributions. Spending the money inside rather than outside CERN is thus a far-sighted strategic investment, even if accepting a dumping offer may seem less expensive at short term.

7.- It is therefore recommended, in due respect for outside experts and in full consideration of the difficult econmic context, to concentrate all ressources on a CERN development and to carry out the complete Laser Ion Source RFQ project in-house.

W. Pirkl
16 May 94